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Introduction

No more marking – online assignments are here! Can it really be that simple? We are three university-level math instructors who describe our experience creating and managing online assignments. Our goal is to elaborate on various issues related to this learning tool, and to convince our reader that online assignments have their place in post-secondary pedagogy.

We use the term *online assignment* to denote a set of questions and problems that are posted, submitted, graded and recorded electronically through a learning management system (LMS) of choice. Over the last decade, the use of online assignments in teaching post-secondary subjects has been extensively researched in the areas of physics and chemistry (Carrier & Jones 2004; Riffell & Sibley 2004). Recently, research papers about the use of online assignments in mathematics have started to emerge (Krbavac 2006; Ledder 2009; Segalla & Safer 2006; York, Hodge & Richardson 2008). In general, online assignments have been seen as part of a move towards innovative, technologically improved and enhanced teaching and learning at many universities and colleges (Carrier & Jones 2004).

A common theme in research on the role of technology in classrooms is: How can technology be used in teaching so that students benefit the most? As Guess (2007) puts it,"The question, then, is: How can educators adapt their teaching methods to emerging technologies? And should they?" We note that this challenge of determining the place of technology in teaching and learning is not new. In 1972, Lacey wrote about using films in a classroom and was faced with the same questions. The aim of this article is to support the view that educators should adapt their teaching methods to emerging technologies only if that change will benefit student learning and be feasible for instructors and institutions. We intend to demonstrate that many of the challenges posed by using technology in teaching and learning can be overcome with careful planning.

In this paper, we describe our experience creating and using online assignments for several calculus classes at Simon Fraser University (SFU). We present our findings on the suitability of available software by considering the needs and perspectives of instructors, students and administrators. We provide a list of questions to guide an instructor in choosing online assignment problems and a list of benefits and challenges associated with this endeavor. In an attempt to contribute to the discussion about the role of technology in classrooms, we propose a balanced use of both paper and online assignments in math classes. In support of our findings, we offer survey data from our science, engineering and social-science calculus subjects over the span of five years. We discuss recent developments and future possibilities for using online math problems, and conclude with a summary of the most important answers to our self-imposed questions about this emerging teaching tool.

Traditional Settings

In the past two decades, students in first- and second-year math subjects at SFU have been asked to submit weekly assignments that consisted of 20 to 25 problems, for a total of 10 assignments per semester. Teaching Assistants (TAs, also known as tutors) marked these assignments. Due to large class sizes – typically between 150 and 500 students – and the limited number of TA hours available for assignment marking, only one or two questions per assignment were marked completely. Hence, students received feedback on a small fraction of their homework. To encourage assignment submission, up to five marks out of ten were awarded just for completing the assignment. The remaining marks were used for grading the chosen questions. Since the

combined homework marks contributed 10% of the overall mark, up to 5% of the total mark was given as an incentive for nothing more than assignment submission.

The cost for the Department of Mathematics at SFU with this type of marking was significant. For example, in a typical fall semester there are about 2,000 SFU students enrolled in first-year calculus. TAs are usually paid for one minute per question per assignment paper they mark. This minute not only includes actually grading the problem, but also the time allowed for collecting assignments, recording marks and returning assignments. Just marking one question on all of the 10 assignments requires about 333 TA hours per semester.

This arrangement led to a situation in which students received practically no feedback on their assignments, instructors were not assured that students practiced concepts and developed skills sufficiently, and the costs of marking those assignments seemed inefficiently spent. These facts were the main reasons that the Department decided to introduce online assignments for its science/engineering calculus subjects in the summer semester of 2003. SFU subsequently adopted online assignments for the social-science calculus sequence in the autumn semester of 2004. Similarly motivated moves to online assignments have been documented in the past decade, especially for physics (Kashy et al. 1993; Thoennessen & Harrison 1996; Bonham, Beichner & Deardorff 2003; Demirci 2007), and, recently, for mathematics (Seppälä, Caprotti & Xambó 2006; Segall & Safer 2006; York, Hodge & Richardson 2008; Ledder 2009).

Software in Support of Online Assignments

There are numerous educational-software packages that support online assignments. It has become a standard for publishing companies to accompany their calculus and other math and science textbooks with software that supports online assignments. For example, software known as PHGradeAssist accompanies the standard textbook *Calculus Early Transcendentals Version* (Edwards & Penney 2002). Another example is the software package known as WebAssign, originally developed by North Carolina State University, that accompanies the popular textbook *Calculus: Early Transcendentals* (Stewart 2002). Some commercial companies, such as Lyryx Learning based in Calgary, AB, and Maplesoft from Waterloo, ON, offer to create questions as part of their courseware packages or to use existing question banks for online assignments. In addition, many commercial learning management systems, like WebCT, come with online quiz-creation capabilities. Beyond commercial software options, there are also open source packages that support online assignments. Two examples are LON-CAPA, developed by Michigan State University, and WebWorK, from the University of Rochester Department of Mathematics.

The following is a list of some of the basic features of existing software packages that support online assignments:

- Browser-based interface
- Question banks
- Various types of questions
- Parametrically generated questions (i.e., random selection from a pool of slightly different versions of the same question)
- Automatically graded assignments
- Electronic grade book
- Communication tools

Question banks may be provided or purchased, as in the case with software that accompanies textbooks, or shared, as is the case with all open-source software. Almost all packages allow instructors to create their own questions. The questions appear in a variety of formats, including multiple-choice, true/false, fill-in-the-blank with a formula, numerical value, string answer or open-ended. Communication tools usually include chat rooms, a discussion board and an internal mailing system.

Questions to Guide an Instructor in Choosing Online Assignment Problems

It is our experience that an instructor preparing a set of problems for an online assignment faces the same challenges regardless of whether the questions are created from scratch, modified from previous versions or chosen from an open-source or commercial question bank. Some questions that arise when an instructor is creating an online assignment include:

- *How can we choose online assignment questions that will best complement other elements of the subject such as lectures, readings, paper assignments and exams?*
  In an attempt to make our students read the textbook and go through their class notes on a regular basis, we created a series of true-false questions, matching questions and fill-in-the-blank problems. These were constructed to be concept-driven and not dependent on any textbook. Furthermore, in an attempt to offer more guidance to our emerging problem-solvers, we composed questions that required students to enter missing details of each step of the solutions.
- *What types of online questions are best suited for learning various mathematical concepts and skills?*
  Different concepts may require different types of questions. For example, evaluating 1+1 would require a *numerical-response question*. Finding the average of numbers 1 and a would require a *formula-response question*. In this case, the system would accept correct answers written in different forms, for example:
  $$\frac{1+a}{2},\ 0.5\cdot(a+1),\ \frac{a}{2}+0.5$$
- *What types of online questions are the most appropriate for testing complex math ideas?*
  We find that we often resort to combining several question modes to present a more complex problem. A typical example in first-year calculus is the problem of sketching a graph of a given function. Online problems of this type that we constructed were combinations of several multiple-choice, fill-in-the-blank, formula and numerical-response questions. After students respond with a sequence of correct answers, the final click displays the graph of the function! We have also learned that feedback from students can be used to enhance the presentation and tease out the best format. In the system that we currently use, each online question is accompanied with a feature called *Send Feedback*. This feature has three settings: feedback to resource author, question about resource content and question/comment/feedback on class policy. For example, students pointed out that the solution of a particular problem required several steps, but that they were asked to submit only the final answer. If the answer was incorrect, the students would not know where they went wrong and could not address their own problem-solving errors. We responded by breaking down the problem to require step-by-step answers and give hints along the way based on common errors.

- *Can online questions be used to communicate mathematical ideas, i.e. be used to introduce key concepts or applications that have not been seen in the lecture or the textbook?*
  The possibilities around creating an online assignment question are limited only by the degree of the author's imagination and the intention of the instructor. Online assignment questions can contain pictures, applets, web links, animations, clips from movies and so on. This flexibility allows the instructor to present material relevant to topics that would otherwise be beyond students' reach. For example, an online electronic medium is the right environment to introduce some of the concepts that play important roles in contemporary mathematics, like a visual proof of a mathematical fact or some basics of experimental mathematics. Furthermore, we use online assignments to introduce our students to the correct way of presenting written mathematics. For example, if we ask a student to prove a certain property by using a particular theorem, we write the answer in the proper form, using the appropriate mathematical phraseology and notation. In the text of the proof we leave blanks that the student needs to fill in. Hence the student is put in a position of being an active participant in the development of a mathematical proof.
- *To what degree should online assignments be used for drill exercises?*
  Online assignments are an ideal medium for repetitious exercises that are often a necessary step for a student to perfect a math skill or procedure. The challenge for an instructor is to resist the temptation to overuse this aspect of online assignments and make the task too monotonous. Our experience with online drills is that less is more. However, when accompanied by a string of appropriate hints, these exercises become an efficient and convenient tutorial tool. For example, consider the problem to evaluate $3-2\cdot(-1)$. There are three common erroneous answers: 0, 1, and -1. The first answer, 0, is obtained when students do not note the multiplication sign. Hence if a student enters "0" as their answer, the question "Did you do the multiplication?" would pop up. The answer "1" would be accompanied with the hint, "What can you tell about the product of two negative numbers?" The answer "-1" would be matched with the hint, "What is the order of operations?"
- *Are the available online questions suitable for any teaching style?*
  In our experience the answer to this question varies from instructor to instructor. The responses range from, "I've been successfully teaching in my own way for years" to "The online questions are too simple (or too complicated) to really contribute to student's learning." Although not everyone sees the value of using online tools for testing mathematical knowledge, we have experienced that some of our most skeptical colleagues started using online assignments in their classes after getting involved in testing and editing the existing problems or creating online problems on their own. One of the reasons that the pool of online assignment questions in our institution has been steadily growing is that instructors are creating new problems based on their own views and ideas about presenting certain topics.
- *Are the available online questions suitable for any learning styles?*
  Students work on online assignments remotely, within the provided time frame, usually a few days. The fact that students work on their own time requires them to be self-disciplined, organised, independent and resourceful. The resources that students are expected to use are the textbook, lecture notes, discussion-board contributions and the math help centre, which supports the course. The feedback we received from students is that online assignments force them to read the textbook and lecture notes on a regular basis (Figure 1), and helped them better learn the material (Figure 2).

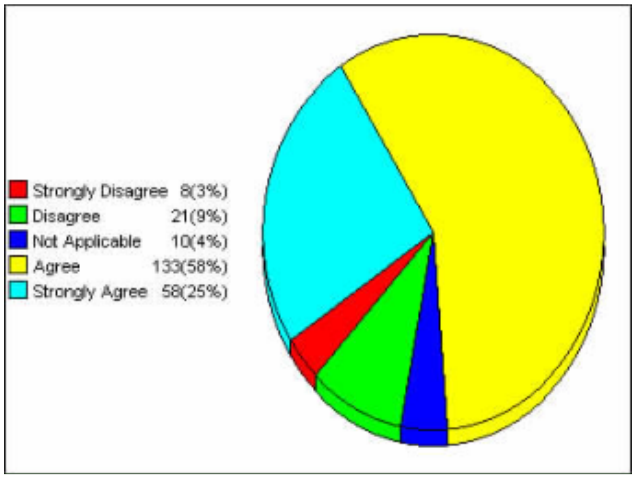

Figure 1 Responses: To complete online assignments I had to read the textbook and lecture notes regularly

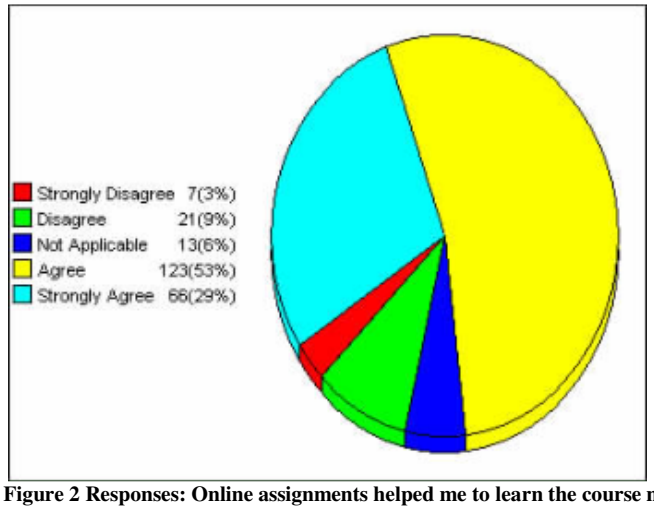

Figure 2 Responses: Online assignments helped me to learn the course material better

- *How can we mimic online what we have observed with paper assignments in our workshops, i.e. support discussion among students for the purpose of learning?*
  Students use an online monitored discussion board, which accompanies each problem, to communicate mathematical questions and ideas among themselves. The fact that a large number of students became involved in these discussions came as a surprise to the authors.
- *How can we avoid cheating?*
  We tried to educate students about the ethical side of cheating and the fact that cheating on homework assignments, or on any other required course work, jeopardises their own learning experience. On the practical side, online technology allows for parametrically generated questions, as mentioned in Section 3, and thus eliminates simple copying of somebody else's answers.

It is our opinion that question banks are a limited resource. However, existing question banks do provide a platform to get started with the creation of online assignments. Publishing companies are

paying more and more attention to this aspect of courseware and, in our opinion, their products can be of a high quality. It is important to notice that commercial systems like PH Grade Assist or Maple T.A. allow users to create new problems or modify existing ones. Many conscientious instructors may wish to create problems themselves, but this requires a substantial investment of time and energy to create questions, deal with the time-consuming task of testing them and soliciting student feedback to improve them. Additionally, such instructors need strong support from the administration to create and implement a new pedagogical tool.

During the seven years of working first with a commercial question bank and then switching to an open-source product, in which we have been using and contributing to shared question banks, we have concluded that an instructor who contributes to a shared question bank must engage with this pedagogy with a whole new attitude. Possibly the most important attitude change for many college and university math instructors is to accept the fact that their teaching is no longer a solitary activity when they become involved with a shared question bank, and they must develop new skills, such as becoming familiar with basics of various software and learning all steps in the process of designing a new question or adapting an existing question. A variety of benefits and constraints are the natural outcome of this endeavor.

Benefits

- Flexibility of product: The questions are not tied to a particular textbook or a specific class. They are easy to change and adjust to meet the needs of the instructor or the students. For example, a question created at SFU for the Introduction To Analysis subject has been used in an algebra course at the Jerusalem College of Engineering (Jerusalem, Israel), a calculus class at Selwyn House School (Montreal, Canada) and a linear algebra class at the University of Applied Sciences (Braunschweig/Wolfenbuettel, Germany).
- Connecting with students: By creating appropriate questions, the instructor makes first-year university students read the textbook in detail and regularly. For example, students might be asked to match parts of definitions and theorems from a given textbook section.
- Creativity: By creating questions for online assignments, instructors can truly unleash their imagination. A single problem might contain various types of questions: multiple choice, drop-down box, fill-in-blanks, click-on-the-image and formula and numerical responses. All this might be accompanied with dynamic plots and supported with hints that match the most common mistakes. Consequently, students get a rich learning resource that might benefit their understanding of the particular topic better than a back-of-the-book math exercise.
- Community building: In our experience this occurs at two levels – at a local level, when a group of instructors from the same institution builds resources that the members of the group can use in their teaching, and at a global level, as in the example provided under *Flexibility of product*.
- Self-enrichment: Emerging software and technology allow instructors to advance their professional development by learning new skills, making changes in the way they teach, creating new learning resources for students and connecting with students using a contemporary medium of learning.

Constraints:

- Inconsistent use of terminology on the part of the instructor: The ambiguous use of terminology can create a stumbling block for students and even instructors. For example,

not everybody agrees that a local extremum of a function might happen at the end point of an interval. Or, what one instructor calls *a critical number* another instructor might call *a critical point*. We find that the most effective way of dealing with these constraints is to be open about them. The instructor should investigate such constraints, alert students to them and, most importantly, state explicitly in online questions which term is being.

- Development of software: When choosing a question from a shared question bank the instructor must be very careful. A common problem with shared question banks is that a question might be created in an early release of the software and might not work properly in the newest version. Questions from shared question banks are accompanied by a so-called metadata page, which contains all basic information about the resource, including the creation date and the last revision date. Those dates could be good indicators of why a question with the cummulative total of a few tens of thousands hits does not work on your screen. In any case, testing a few versions of the question is a must!
- Time commitment: Creating and testing online problems is a time-consuming job, particularly for a beginner. A stubborn bug in the problem code can be very frustrating and can take a long time to find. It is our experience that working on online questions together with colleagues is more efficient.
- Technology can break down: Instructors who use online assignments put themselves in the position that one important component of their classes depends on technology. The LMS might be down at the due time for an assignment or the browser that a student uses might not display the posted question in the best way. These are just two examples of issues that are completely out of an instructor's control. Still, in students' eyes the instructor is the one responsible for everything that is related to the class. Our advice is to have a contingency plan and communicate this in advance to the students. For example, if the server is down, be flexible enough to extend the due date and time. We also release answers with a delay of a few hours to allow for some reaction time in case an issue with the technology arises.
- Can potentially take more time: The management of online assignments requires regular monitoring of discussion boards, often answering students' questions online and sometimes dealing with very frustrated students, and occasioanl adjustments of posted questions. This all can add to an instructor's existing schedule. We have begun to use TAs for monitoring discussion boards to be more time-efficient, and at the same time to give our more senior TAs valuable experience.

SFU Experience with PHGrade Assist, an Early Online Assesment Tool

Simon Fraser University was the first university in Canada to use PH Grade Assist, an online assessment tool developed by Prentice Hall, in teaching calculus classes. The tool was used from the summer semester of 2003 until the summer semester of 2004 for assignments in the science/engineering calculus course sequence (Calculus I – Differential Calculus, Calculus II – Integral Calculus and Calculus III – Multivariable Calculus). The initial idea was to put weekly assignments for the three subjects online and let the system do everything else, including collecting assignments, grading and recording grades. Questions available for online assignments were based on exercises that followed each section in the textbook *Calculus Early Transcendentals Version* (Edwards & Penney 2002). The instructors created the subject online and assigned questions straight from the book. Each student received one of the parametrically generated versions of each assigned question, which ensured that many different versions of the same type of question circulated among the students. Students had to purchase access to the

system via a code provided with the textbook, register, enroll in the subject and do all required work. Codes slightly increased the price of the textbook packages. There was the possibility of purchasing codes separately for $10 CAN in case a student bought a used textbook.

The described approach was extremely convenient for SFU instructors and incurred no extra cost for the Department of Mathematics. The onus of the work was on the students. However, soon it became clear that teaching and learning became disconnected. The instructors' choice of questions was limited by the medium, with no questions of the types *prove*, *graph*, or *give an example*. The students' answers were constrained by the medium, which did not provide any experience with writing down answers as they would in an exam. At the end of this first trial in the autumn semester of 2003, students were surveyed about their experiences with online assignments and paper assignments for understanding, quality and enjoyment. The 409 responses are summarised in Table 1.

Table 1. Summary of Student Survey after Trial of Online Learning System

	Online assignments better	Same	Paper assignments better
Understanding the material	16%	34%	50%
Quality of your work	13%	29%	58%
Enjoyment of the subject	22%	33%	45%

Although the survey results indicated a clear preference for paper assignments, conversations with individual students encouraged us to continue with our online assignment trials. The next step was to use a combination of paper and pencil as well as online assignments, this time allowing for multiple attempts of the online problems to get a correct answer. However, three sensitive issues still remained be resolved to the students', instructors' and department's satisfaction. The most important of them were the increased cost of the textbook package due to the codes required to register into the online assignment system; the lack of variety of mathematical questions; and students being forced to share their personal data with an entity that was not part of Simon Fraser University. These concerns led to the decision that starting in the autumn semester of 2004 the Department of Mathematics would switch to an open-source software package called LON-CAPA, developed by Michigan State University.

SFU Experience with LON-CAPA

LON-CAPA is an open-source freeware web-based course management system developed at Michigan State University in 1993. It supports a variety of disciplines, including physics, chemistry, biology and mathematics, with over 70 participating institutions worldwide. LON-CAPA features content-sharing and content reusability, creation and grading of randomised homework, quizzes or exams, assessment analysis, porting content, one-source/multiple targets, clicker device support and other features. The repository has been steadily growing since its inception in 1993, and as of the summer semester of 2011, there were some 200,000 problems in the LON-CAPA shared-content repository.

The first LON-CAPA server at SFU was installed in May 2001 in the Department of Chemistry under the guidance of Dr. Ray Batchelor, who in the autumn semester of 2001 became the first instructor worldwide to offer chemistry classes using this system. SFU Academic Computing

Services supported the installation of the LON-CAPA system by housing and maintaining the servers (Batchelor & Jungic 2004), which had been purchased by the SFU Faculty of Science purchased these servers. The use of LON-CAPA comes at no additional cost for SFU students, who are automatically granted access to LON-CAPA when they enroll in subjects that use this system. It is important to note that all instructors in the Department of Mathematics at SFU who create and manage online assignments do this as part of their regular teaching assignments, so nor is there is additional cost to the Department.

In the autumn semester of 2004, the Department of Mathematics offered its first subject, Calculus I for Social Sciences, using LON-CAPA for online assignments. The first author of this paper developed most of the questions and managed the LON-CAPA segment of the class. By the autumn semester of 2008, the system supported seven calculus subjects, with five instructors involved in creating problems and managing subjects. All students of these subjects were required to participate in online assignments. Needless to say, we had found a system that was beneficial for the students, the instructors and the administration.

One of the greatest aspects of LON-CAPA is its discussion tool. We observed that students make extensive use of the electronic discussion board to talk about problems with each other. Some students asked for help, but giving only answers was useless since each student had a different problem due to the use of randomisation. Students therefore needed to analyse the problem and explain to each other what steps were needed to solve it. The instructors were quite elated about this outcome, as the students frequently used more mathematical language than the instructors thought possible! Students were also teaching each other necessary concepts and skills. However, occasionally students were stuck with a particular problem or received misguided assistance from other students. The instructors saw the need for assigning TA hours for the supervision and support of the discussion board. This proved to be very effective and only cost about 40 TA hours per semester.

Paper and Pencil vs. Online Assignments

Research indicates that online assignments or web-based homework of the type discussed in this paper neither improve nor harm student learning. See for example Bonham, Beichner and Deardorff (2001), Bonham Beichner and Deardorff (2003) and Demirci (2007). Bonham, Beichner and Deardorff (2001) state that, "All other things being equal, it doesn't make a big difference whether the computer or a human being is wielding the *red pen*. Other factors in a course have a much greater effect on student performance than the *method* of collecting homework and delivering feedback."

In our view, when teaching math classes the main role of paper assignments is to give students an experience of writing mathematics. As Lee states, "You should not confuse writing mathematics with *showing your work*.… A list of calculations without any context or explanation demonstrates that you've spent some time doing computations; however, a list of calculations without any explanations omits ideas. The ideas are the mathematics. So a page of computations without any writing or explanation contains no math." (Lee 2009) Second, paper assignments allow instructors to ask students to prove a statement, demonstrate their problem-solving skills, graph a function to give an example or a counterexample for a particular mathematical phenomenon.[1]

[1] A side effect of paper assignments is that they give an opportunity for teaching assistants to learn and practice marking students' papers.

In our experience the most valuable feature of online assignments is that the medium allows each student in the class to engage with the content and enables the instructor to easily check the history of a student's work. For example, an online assignment that is due before the *second* lecture in the semester makes students start the coursework from day *one*. In our classes we use short, multiple, online assignments that are often closely related to class lectures and definitions, theorems and examples from the textbook. Many of these problems are phrased as multiple choice, true or false and matching questions, rather than in the back-of-the-chapter-exercise fashion. Assignments are due before the next lecture; in this way students have to go through the material after the lecture in which the material is covered. In a survey conducted in a Calculus I class in the autumn semester of 2006, students were asked to respond to the statement, ”To complete online assignments I had to read the textbook and lecture notes regularly.” The summary of 230 answers, given in Figure 1, shows that 83% of students agreed or strongly agreed with the statement.

We also use online assignments as a drill tutor. For example, as an assignment question we post 12 problems of a similar type divided in groups of three, with one submission per group. We anticipate mistakes that students might make and we create hints accordingly. Multiple attempts are allowed.

Research shows that online assignments help students manage their time better (Demirci 2007). Our experience is that online assignments can also cause frustration for some students. In our surveys, students list sources of frustration as: entering answers in an acceptable form, internet malfunction, lack of hints, ambiguous wording, several multiple choice questions with a single submission, programming bugs in questions and misuse of the discussion board. Regardless of the occasional complaints, it appears that the majority of students appreciate online assignments. Figure 2 summarises 230 responses from the autumn 2006 survey statement, “Online assignments helped me to learn the course material better.” In the autumn semester of 2006 an anonymous student neatly summarised the perspective shared by numerous students: “I believe that the short online assignments definitely changed my homework experience. It forces the user to read the directions and follow them to the letter. The unequivocally ruthless marker (the computer) definitely enhanced my ability to be meticulous.”

We propose that paper-and-pencil assignments be used in conjunction with online assignments in undergraduate mathematics subjects. Our practice is to assign a weekly, two-part paper assignment. The first part, *Instructor’s Questions*, contains a few problems that we make ourselves or choose from any available source – an old exam, for example. These problems are relatively complex, and their solutions require deeper understanding of the material. One or two of them are fully marked. The second part, *Practice Questions*, contains about a dozen back-of-the-chapter exercises from the textbook. These exercises are not marked, but each student receives marks for submitting the assignment. Solutions for all problems are posted weekly, after the assignment’s due date. Online assignments, posted after each lecture, are due thirty minutes or one hour before the next lecture. These assignments contain two or three questions, and multiple attempts are allowed. Usually the paper assignments contribute 8% and the online assignments contribute 7% to the total mark.

Recent Developments and Future Possibilities of Using Online Problems

Our ambition is to expand online assignments from a tool that quizzes students on weekly topics to a tool that can provide a continuous survey of various mathematical skills and concepts. This will allow instructors to keep track of students' ongoing learning. The calculus online assignments have

served as a springboard to applications and new initiatives throughout the undergraduate mathematics curriculum in the Department of Mathematics at SFU. We list some of the recent developments and future projects.

- The implementation of online assignments – not only in calculus classes but also in the *Pre-Calculus*, *Foundations of Analytical and Quantitative Reasoning* (which prepares students for pre-calculus), *Principles of Mathematics for Teachers* and *Introduction To Quantitative Reasoning* courses – is completed.
- In September 2006, the Department of Mathematics started using LON-CAPA for its Quantitive Placement Test and Calculus Readiness Test, which are meant for newly admitted SFU students whose mathematical knowledge needs to be assessed before directing them to an appropriate math subject. The tests are conducted online in a controlled environment with an invigilator present and with a time constraint. Practice tests are posted on the department's website and are accessible to all interested students.
- Faced with the reality that a significant number of first-year students, even if they formally satisfy prerequisites, are not ready to take a calculus subject, the Department of Mathematics introduced a diagnostic test in 2007. LON-CAPA's capacity to create parametrically generated questions is used to make several versions of a multiple-choice test. Students enter their answers on a *bubble sheet* by filling in the bubble that matches their answer. LON-CAPA is also used to read and record completed bubble sheets. The test, written during the first week of classes, has as its main purpose to function as an early warning for those students who need additional help. The Department provides that help through Calculus Support Sessions.
- An online tutoring mechanism has been created for students involved in the Calculus Support Sessions. The idea here is two-fold. First, we wanted to give students more practice with immediate feedback on their own time. Two problems with real people as tutors are inconsistency between tutors and lack of feedback, as has been investigated by Connolly (2009). These problems can be completely avoided using an online tutoring system. Many online questions are set up with the hint feature. These hint features are based on common student mistakes in thinking and thereby used to redirect their reasoning. Second, we wanted to help students reflect on their learning. We noticed that the vast majority of students who failed the diagnostic test not only had a weak background in skills and concepts leading up to calculus, but also had poor learning strategies. There is a need for structure and purpose to guide students' learning so that they are active participants in their own learning, learning of discipline knowledge and metacognitive knowledge occurs and the students monitors their learning through reflective thinking (Connolly 2009). If constructed well, online problems can be very successful in providing this structure, and can ultimately help a student succeed in calculus.
- The first and third author jointly created *A Collection Of Problems in Differential Calculus*, a collection of LON-CAPA versions of problems given in SFU Calculus I final exams in the period 2000-2008. The purpose of the collection is to provide an additional online learning resource for students taking a differential calculus subject at SFU.

Conclusion

We propose that online assignments be used in conjunction with paper-and-pencil assignments in undergraduate mathematics classes. The main role of paper-based assignments is to give students an experience of writing mathematics. In addition, they allow instructors to ask students to prove a

statement, demonstrate their problem-solving skills, graph a function or give an example or a counterexample for a particular mathematical phenomenon. The main role of online assignments is to provide students, instructors and academic institutions with a useful, efficient and low-cost assesment and tutoring tool. The two biggest challenges for an instructor creating and managing online assignments is that both tasks are time-intensive; by sharing online questions, teaching no longer remains a solitary activity and individual instructors can save time. This paper has addressed these and other challenges, but also described many benefits of this pedagogy. The most important benefits of online assignments include that students receive immediate feedback and build a learning community. Further, online assignments allow the construction of creative questions; this can contribute to the instructor's self-enrichment. Online assignments engage each student in the class with the content and allow the instructor to easily follow students' development. This paper provides some guidance to instructors willing to try out online assignments.

We aim for holistic teaching and learning rather than linear instruction. Our goal is to avoid the confusion students feel when an instructor moves from one topic (i.e., textbook section) to another without connecting these topics. We would like to encourage instructors to develop online problems that combine a variety of topics, thus ensuring ongoing learning and a continuous application of relevant skills and concepts.

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